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ABSTRACT

Presented are basic concepts of chemistry necessary for operators who manage drinking water treatment plants and wastewater facilities. It includes discussions of chemical terms and concepts, laboratory procedures for basic analyses of interest to operators, and discussions of appropriate chemical calculations. Exercises are included and answer sheets provided. (RE)

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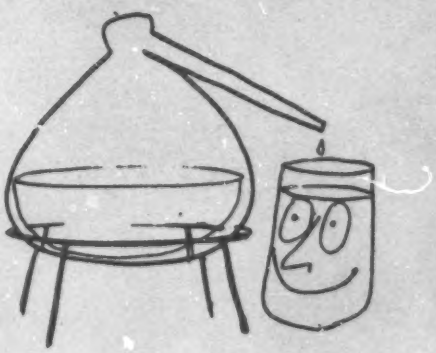
INTRODUCTION TO CHEMISTRY

FOR WATER AND WASTEWATER TREATMENT

Plant Operators



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WATER AND WASTEWATER

TRAINING PROGRAM

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INTENDED FOR TRAINING USES

BASIC CHEMISTRY FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS

To fully and effectively treat water for drinking and industrial purposes; treat wastewater in the larger mechanical-biological plants in South Dakota, you must have an understanding of basic chemistry. Since most advanced water and wastewater treatment processes require chemical treatment, an understanding of chemistry will provide you with an insight to the various treatment processes and some of the laboratory procedures. The study of chemistry raises many different and challenging problems; therefore you must understand the use of chemical terms. Before we progress further in the lesson, read and understand the following chemical terms:

CHEMICAL TERMS

Chemistry - Chemistry is the study of the composition of matter.
Matter _ Matter is anything that occupies space and has weight.
Atom - Atom is the smallest part of an element.
Molecule - A molecule is the chemical combination of two or more atoms. It is the smallest particle of a compound and cannot be broken down without destroying the compound.
Symbol - Symbols are abbreviations for elements. Every symbol stands for an atom of that element.
Formula - A combination of symbols used to denote the composition of a molecule.
Atomic Number - Atomic number is equal numerically to the number of planetary electrons outside the nucleus.
Atomic Weight - The atomic weight of an element is the weight of an atom of the element compared with the weight of an atom of oxygen, having an atomic weight of 16.
Molecular Weight - Molecular weight is the sum of the atomic weights of all the atoms in a molecule.
Equivalent Weight - The equivalent weight of a substance is the molecule weight divided by the total charges of the plus or minus parts of the molecule.
Valence - Valence is the combining capacity of an element to form compounds. Valence is also the displacing power of an atom of hydrogen compared with one atom of the element.
Equations - An equation is a shorthand method of showing the change which takes place in a chemical reaction.
Ion - An ion is an electrically charged atom or group of atoms.
Cations - Cations are positively charged ions.
Anions - Anions are negatively charged ions.

BASIC CHEMISTRY I

Every substance has a specific weight as we experience in our day to day living. For example, a bushel basket full of sand is much heavier than the same basket full of dry sawdust. This same principle applies in chemistry, and is the basis for a lot of calculations and determinations. Over the years, chemists have separated the elements, and they have weighed them, in comparison to each other. Taking oxygen as the base weight of 16.0000, they have found that hydrogen is just about one sixteenth as heavy as oxygen, or to be exact 1.008. In this manner, by comparing the weights of each of the elements, a series of atomic weights have been determined. A table of these weights for the common elements is included in this lesson. (See page 10 .)

The table also includes the symbol, or shorthand notation for each of the elements included. These are the symbols used in chemical reaction equations.

Notice that no units are given for the weight of the elements. The application of any weight system will work for the numbers given. For instance, one atom of oxygen (O) weighs 16 units. Also, one atom of iron (Fe) weighs 55.84 units.

Now, if we have 16 pounds of oxygen, we will have the same number of atoms as we would have in 55.84 pounds of iron. Further, if one molecule of oxygen would unite with one molecule of iron, then 16 pounds of oxygen would unite with 55.84 pounds of iron, because the number of atoms of each element would be equal. This would also be true for 16 grams of oxygen requiring 55.84 grams of iron, or 16 tons of oxygen requiring 55.84 tons of iron.

This is why weight units are not given in atomic weight tables. You may apply your own dimensions to the system you are working in.

We said that one molecule of iron would combine with one molecule of oxygen. We can represent this as an equation.

$$Fe + O \longrightarrow Fe\ O$$

This equation says that one atom of Fe has united with one atom of O to form one molecule of iron oxide (Ferrous Oxide). We knew the weight of each atom in the compound, so we can very simply find the weight of one molecule by adding the weight of each atom in it:

$$55.84 + 16.00 \longrightarrow 71.84$$

This is the molecular weight of Ferrous Oxide. The molecular weight of any compound can be determined in this way. For example

Hydrochloric acid - HCl

From the table we get

H	=	1.008
Cl	=	35.46
HCl	=	36.468

Sodium Hydroxide - Na OH

Na	=	23.00
O	=	16.00
H	=	1.008
Na OH	=	40.08

4

Sulfuric Acid - H_2SO_4

In this case we have the small numbers often seen in a formula, called subscripts, which tell us the number of atoms of each element in one molecule of the compound. In one molecule of H_2SO_4 there are 2 H atoms, and 4 oxygen O atoms. Each atom has the weight given in the table

H	= 1.008 x 2	=	2.016
S	= 32.06	=	32.06
O	= 16.00 x 4	=	64.00
H_2SO_4	=		98.076

Similarly:

Sodium Carbonate - Na_2CO_3

Na	= 23.00 x 2	=	46.00
C	= 12.00		12.00
O	= 16.00 x 3	=	48.00
Na_2CO_3	=		106.00

VALENCE

The next fact we must understand is that of valence. The valence of a compound is the number of H^+ ions or OH- ions it will unite with. The valence of some compounds and elements is fixed, while the valence of others will change from one reaction to another. We will list the more important ions, and their valence here:

H^+ =	$+1$	Hydrogen
Na^+ =	$+1$	Sodium
Ca^{++} =	$+2$	Calcium
K^+ =	$+1$	Potassium
$(OH)^-$	-1	Hydroxyl
O^{--}	-2	Oxide
(NO_3)-	-1	Nitrate
(SO_4)--	-2	Sulfate

Cl	-1	Chlorine
(CO_3)--	-2	Carbonate
(HCO_3) -	-1	Bicarbonate

Water ionizes under the heading of pH. * The water, H_2O, splits into two ions as follows: *See N.Y. Manuals.

$$H^+ \quad OH^-$$

The valence of a substance is the number of H^+ ions or OH^- ions required to react with one ion of that substance. The ions are electrically charged, and since like charges repel and unlike charges attract, the plus ions will react with the negative ions, and vice versa, consider sodium:

One ion of Na will react with one hydroxyl ion, forming NaOH, which is sodium hydroxide (caustic soda, lye).

$$Na^+ + OH^- \longrightarrow Na\,OH$$

The valence of sodium is $^+1$.

One ion of Potassium (K^+) will unite with one hydroxyl ion to form KOH, which is caustic potash. (Potassium hydroxide).

$$K^+ + OH^- \longrightarrow KOH$$

The valence of potassium is plus 1.

Calcium (Ca) is a bit different. It takes 2 hydroxyl ions to unite with one calcium ion.

$$Ca^{++} + 2\,(OH^-) \longrightarrow Ca(OH)_2$$

The valence of Calcium is $^+2$.

The valence of a metallic or plus ion is the number of hydroxyl ions required to react with one ion of the metallic substance.

Perhaps more important are the negative ions. The valence of a negative ion is the number of hydrogen ions required to react with one ion of the substance.

For example, each oxygen ion will react with two hydrogen ions:

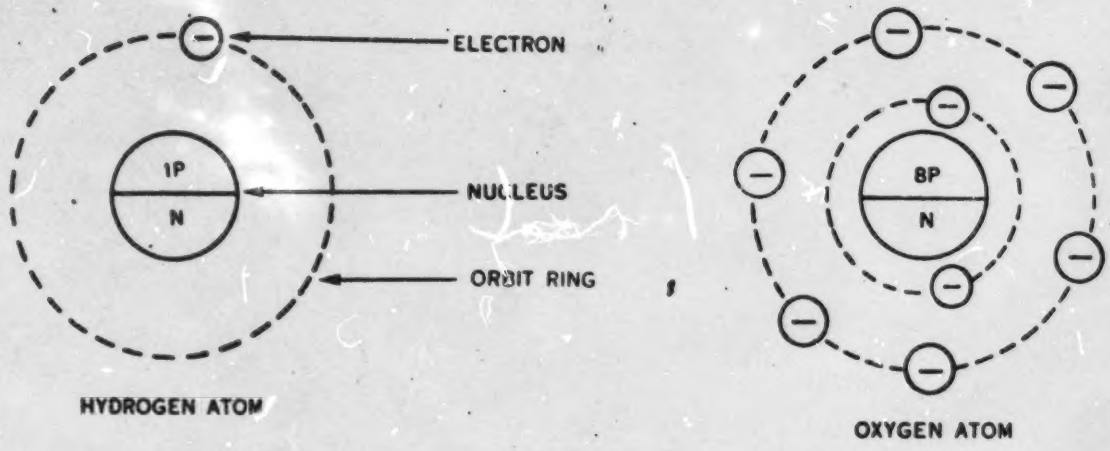
$$2\,H^+ + O^{--} \longrightarrow H_2O$$

The valence of oxygen is minus two.

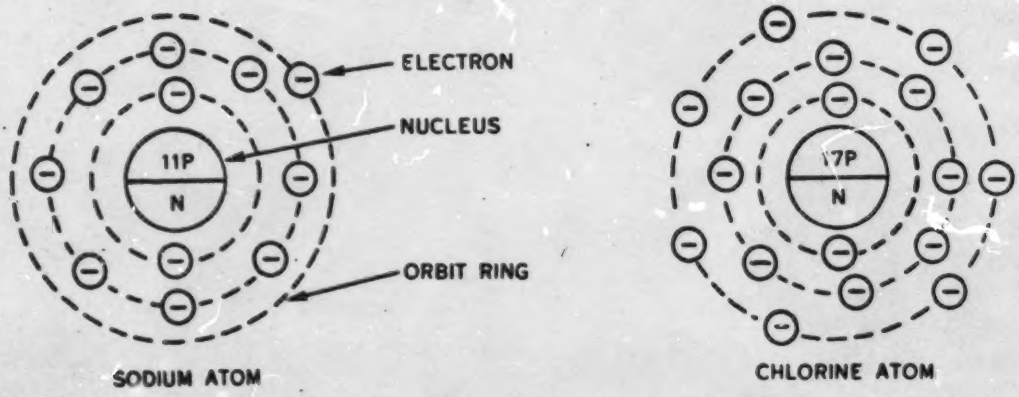
One Nitrate ion (NO_3) will react with one hydrogen ion

$$H^+ + (NO_3)^- \longrightarrow HNO_3$$

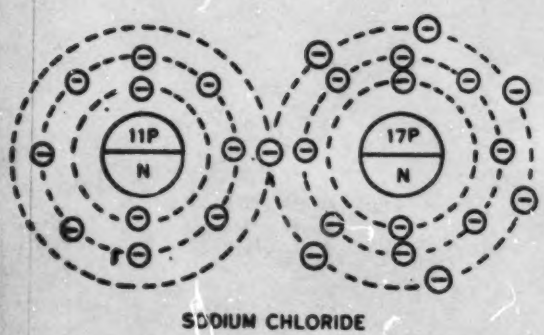
The valence of the nitrate radical is minus one.



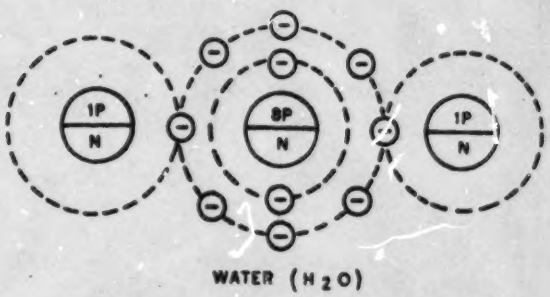
Hydrogen atom and oxygen atoms.



Sodium and chlorine atoms.



Molecule of table salt.



Molecule of water.

One sulfate ion (SO_4) will unite with two hydrogen ions.

$$2\ H^+ + (SO_4) \longrightarrow H_2SO_4$$

The valence of the sulfate radical is minus two.

This particular reaction is very important to the laboratory, and the compound formed is sulfuric acid.

(H_2SO_4)

There is a very important concept which is used over and over in a laboratory.

That concept is the equivalent weight of a substance. Since we usually deal in grams in a laboratory, this weight is usually the gram equivalent weight of a substance.

The gram equivalent weight of a substance is the number of grams of the substance required to react with one gram of hydrogen:

Let us consider the substance

Sodium Chloride NaCl

The molecular weight of NaCl is

	Na	= 23.00
	Cl	= 35.46
NaCl		= 68.46

One gram molecular weight of NaCl = 68.46 grams.

Now, if we placed this salt in a solution where there were many H^+ ions could take the place of the Na^+ ions.

As stated previously there are the same number of atoms in one gram atomic weight of each element. If we have one gram molecular weight of NaCl (68.46 gm), then we have one gram atomic weight of Na (23.00) and if the H^+ ions replace the Na we will get

$$H^+ + NaCl \longrightarrow HCl + Na^+$$

and we will need as many H^+ atoms as we had Na atoms.

The weight of the H atoms will be 1.008 gm (rounded off to 1 in ordinary use). We see that one gram molecular weight of NaCl will react with one gram of hydrogen. This is its equivalent weight.

Suppose however, we are working with sodium sulfate Na_2SO_4. The molecular weight of this compound is

Na	=	23.00 x 2	= 46.00
SO_4	=	96.06	= 96.06
Na_2SO_4	=		142.06

One gram molecular weight of this substance is 142.06 grams.

If we place this amount of Na_2SO_4 in solution, and replace the Na with H^+, we would get:

$$Na_2SO_4 + {}_2H^+ \longrightarrow {}_2SO_4 + {}_2Na^+$$

In this case we see that each SO_4^{--} ion needs two H^+ ions to balance its charge. If we remember that one gram atomic weight of any element has the same number of atoms, we can see that replacing the 46.00 grams of sodium (which is two <u>atomic</u> weights) will require 2 gram atomic weights of hydrogen

2 x 1.008 = 2.016 gm
or rounded off 2 x 1 = 2 gm

The definition of an <u>equivalent</u> weight was the amount of substance required to react with one gram atomic weight of hydrogen. In this case, we must divide by 2 in order to find this amount.

$$\frac{142.06}{2} = 71.03 \text{ gm}$$

is the gram equivalent weight of Na_2SO_4.

The rule for finding the gram equivalent weight of a substance is to divide its gram molecular weight by the valence of the highest charged atom.

Example:	K = 39.1
Potassium Hydroxide	O = 16.0
	H = 1.0
Mol. Wt. = 56.1	56.1

The valences of K and OH are

K = +1, OH = -1

equivalent weight = $\frac{56.1}{1}$ = 56.1

Example: K_2SO_4 Potassium Sulfate

K	= 39.1 x 2	= 78.2
SO_4	=	96.06
Molecule weight = 174.26		174.26

K = +1, SO_4 = -2

Equivalent weight = $\frac{174.26}{2}$ = 87.13

(because SO_4 has valence of -2).

Example: Na_2CO_3 (Sodium Carbonate)

Na	=	23.00 x 2	= 46.00
C	=	12.00	12.00
O	=	48.00	

Molecule weight Na_2CO_3 = 106.00

Na = +1 CO_3 = -2

Equivalent weight = $\frac{106.0}{2}$ = 53.0

Example: H_2SO_4 (Sulfuric Acid)

H	= 1 x 2	= 2.0
SO_4	=	96.06
Mol. Wt. H_2SO_4	=	98.06

H = +1 SO_4 = -2

Equivalent weight = $\frac{98.06}{2}$ = 49.03

BASIC CHEMISTRY I

1. What does the symbol K designate?
2. What is the atomic weight of an element?
3. Why are there no units for atomic weights?
4. What do we know about the number of atoms in one gram atomic weight of any element, compared to the number of atoms in one gram atomic weight of another element?

Find the Molecular weights of the following substances:

5. HNO_3 (Nitric Acid)
6. NaN_3 (Sodium Azide)
7. $NaHCO_3$ (sodium Bicarbonate)
8. $KMnO_4$ (Potassium Permanganate)
9. CaO (Lime)
10. $MnSO_4$ (Manganous Sulfate)
11. $Na_2S_2O_3$ (Sodium Thiosulfate)
12. KI (Potassium Iodide)
13. $MnO(OH)_2$ (Basic Manganic Oxide)

10

14. NH_4Cl (Ammonium Chloride)

15. What is the valence of a compound?

Find the equivalent weights of the following substances:

16. $K_2(SO_4)$

17. NaOH

18. $Ca(OH)_2$

19. $Mn(SO_4)$

20. $NaNo_3$

21. CaO

22. BaSO4

23. $Na_2(S_2O_3)$

24. $K_2(CO_3)$

25. $H2SO_4$

26. H_2CO_3

27. H_2S

Element	Symbol	Atomic No.	Atomic Weight
Aluminum	Al	13	26.97
Barium	Ba	56	137.36
Bromine	Br	35	79.92
Calcium	Ca	20	40.08
Carbon	C	6	12.00
Chlorine	CI	17	35.46
Chromium	Cr	24	52.00
Copper.	Cu	29	63.57
Hydrogen	H	1	1.008
Iodine	I	53	126.932
Iron	Fe	26	55.84
Lead	Pb	82	207.20
Magnesium	Mg	12	24.32
Manganese	MN	25	54.93
Mercury	Hg	80	200.60
Molybdenum	Mo	42	96.00
Nitrogen	N	7	14.008
Oxygen	O	8	16.00
Phosphorus	P	15	31.02
Platinum	Pt	78	195.23
Potassium	K	19	39.10
Silicon	Si	14	28.06
Silver	Ag	47	107.88
Sodium	Na	11	23.00
Sulfur	S	16	32.06
Zinc	Zn	30	65.40

NAME	SYMBOL & CHARGE	NAME	SYMBOL & CHARGE
Acetate	$C_2H_3O_2^-$	Hydroxide	OH^-
Aluminum	Al^{+++}	Hypochlorite	ClO^-
Ammonium	NH_4^+	Iodate	IO_3^-
Antimony	Sb^{+++}	Iodide	I^-
Barium	Ba^{++}	Lead (plumbous)	Pb^{++}
Bicarbonate	HCO_3^-	Magnesium	Mg^{++}
Bismuth	Bi^{+++}	Manganous	Mn^{++}
Bromide	Br^-	Mercurous	Hg^+
Cadmium	Cd^{++}	Mercuric	Hg^{++}
Calcium	Ca^{++}	Nickel	Ni^{++}
Carbonate	$CO_3^=$	Nitrate	NO_3^-
Chlorate	ClO_3^-	Nitrite	NO_2^-
Chloride	Cl^-	Oxalate	$C_2O_4^=$
Chlorite	ClO_2^-	Oxide	$O^=$
Chromate	$CrO_4^=$	Perchloride	ClO_4^-
Chromic	Cr^{+++}	Permanganate	MnO_4^-
Cobaltous	Co^{++}	Phosphate (ortho)	$PO_4^{\equiv}$
Cupric	Cu^{++}	Potassium	K^+
Cupric Ammonia	$Cu(NH_3)_4^{++}$	Silicate (ortho)	$SiO_4^{\equiv}$
Cuprous	Cu^+	Silver	Ag^+
Cyanide	Cn^-	Sodium	Na^+
Dichromate	$Cr_2O_7^=$	Strontium	Sr^{++}
Ferric (iron)	Fe^{+++}	Sulfate	$SO_4^=$
Ferricyanide	$Fe(CN)_6^{\equiv}$	Sulfide	$S^=$
Ferrous (iron)	Fe^{++}	Thiosulfate	$S_2O_3^=$
Fluoride	F^-	Tin (stannous)	Sn^{++}
Formate	HCO_2^-	Zinc	Zn^{++}

Valance of common ions.

BASIC CHEMISTRY II

Previously, we discussed the atomic weights of elements, the molecular weights of compounds, and the equivalent weights of substances. In this section we will discuss the normal system of solutions.

A NORMAL solution is one that contains one gram equivalent weight of SOLUTE in one liter of SOLUTION.

A SOLUTION is a mixture of two or more substances, and at least one of the substances is a liquid. Both of them can be but this is not necessary. In a solution, you cannot separate the two substances by filtering. They are too finely divided, and the mixture appears to be homogeneous or uniform.

There are two parts to a solution, which are as follows:

The SOLUTE, or the material which is being dissolved. The solid material put into the liquid is always the solute.

The SOLVENT is the liquid substance into which the solid material is dissolved. In most of our lab solutions, water is the solvent we use. This is not always the case, and such things as alcohol can be a solvent.

Lets take another look at the definition of a normal solution. We said that there is one gram equivalent weight of solute per liter of solution. If we look at this carefully we can see that the solid material, or solute, is measured by weight, while the solution itself is measured in liters, which is a volume measure.

There is a great advantage in this weight-volume relation.

If we dissolve one pound of sugar in one gallon of water, then we know that we will have one half pound of sugar in one half gallon.

Similarly, we also know that in one quarter of a gallon, we will have one quarter of a pound of sugar.

In the laboratory, the same relationship is utilized, except that we use different units of measurement. For example, suppose we have 10 grams of salt dissolved in enough water to make 1000 ml (one liter). Then in 100 ml we would have 1 gm of salt, and in 10 ml we would have .1 gm. This weight volume relationship is easily worked by proportion.

How many gm of salt is there in 258 ml of the above solution

$$\frac{258.\ \text{ml}}{1000\ \text{ml}} = \frac{x\ \text{gm}}{10\ \text{gm}}$$

$x = 2.58$ gm

14

All of the laboratory glassware is marked in liters and milliliters. We have graduate cylinders, volumetric flasks, pipettes and burettes. This equipment measures the volume of solution we use in our various tests. The computation of the weight relationship expressed above is the method by which we determine our results.

A normal solution is a very special case of the weight volume relation of solutions. As we said in our definition, there is one gram equivalent weight of solute in one liter of solution. Let us make a 1 N (normal) solution of salt. The formula for salt is

Na Cl

Referring to our table of atomic weights, we will determine the molecular weight of this compound

Na = 23
Cl = 25.5
Molecular wt. = 58.5

One gram molecular weight of salt is 58.5 grams.

Checking the equivalent weights, we see that the sodium (Na^+) ion is $^+1$, and the Chlorine (Cl^-) ion is $^-1$. The equivalent weight is 58.5 grams.

To make a 1 normal solution of NaCl we would very carefully weigh out 58.5 grams of salt on a balance, and add it to about 300 ml of distilled water to a volumetric flask. After thorough mixing, add more distilled water to the flask until we have 1 liter of solution.

Notice that we do not add the NaCl to one liter of water. There is a little less than a liter of water in a liter of solution because the salt will occupy some volume. Rather, we dilute the salt to a final volume of one liter.

Another example: A 1N (normal) solution of Sodium Hydroxide (NaOH). The molecular weight is:

Na 23
O 16
H 1
NaOH

The valence of Na^+ is 1, so the equivalent weight is 40.

We add 40 grams of NaOH to about 300 ml of distilled water and dissolve, then dilute to one liter.

Not all normal solutions can be computed from the molecular weight, because of the difference in equivalent weight. Consider a 1N solution of sodium carbonate ($Na_2 CO_3$).

The molecular weight is

Na	=	23 x 2	= AG
C	=	12	= 12
O	=	16 x 3	= 48
Na_2CO_3	=		106

Referring to our chart we see that CO_3^{--} has a valence of $^{-}2$, so we must divide the molecular weight by 2 to get the equivalent weight:

$$\frac{106}{2} = 53 \text{ gm equivalent weight}$$

As before we would dissolve 53 grams in about 300 ml and dilute to a liter in order to get a normal solution.

Another example:

1 N H_2SO_4

Molecular Wt.	= H	= 1 x 2	= 2
	S	= 32	=32
	O	= 16 x 4	=64
	H_2SO_4		=98

Valence $(SO_4)^{--} = 2$

Equivalent Wt. $= \frac{98}{2} = 49$

45 grams of H_2SO_4 diluted to one liter will produce a one normal solution.

A normal solution, or a 1N solution contains exactly one equivalent weight of solute per liter. We do not always want a solution of exactly this strength, so we must have a method of expressing all concentrations of solutions. Where in a normal solution we had exactly one equivalent weight, we labeled it 1N. In a solution with one half of an equivalent weight we label it .5N.

Example: Mix a 2N solution of NaOH. The equivalent weight of NaOH is 40, so N = 40 grams

2 (40) = 80 gm per liter = 2N

Example: Mix a .5N solution of NaOH. Equivalent weight is 40, so N=40

.5 (N) = .5 (40) = 20 gm per liter = .5 N

We must again consider compounds with valences other than 1.

Example: Mix a .02N solution of Calcium Carbonate ($CaCO_3$).

The molecular weight is 100.

Ca^{++} has a valence of 2, so the equivalent weight is 50.

N = 50 .02 (50) = 1.0 gm per liter. In this instance one gram of $CaCO_3$ per liter will be all of the material needed.

Most of the solutions we use will be low concentration.

We frequently use a .02N solution of H_2SO_4 or an .02N solution of NaOH. These are computed as the examples above.

We do not always wish to make one liter of a solution. Sometimes we want more, sometimes we want less. We must be able to calculate desired weights of substances for various volumes of solution.

For example: Suppose we want 500 ml of 1N KOH. We start as before and determine the equivalent weight to be 56, so that 56 grams per liter will suffice. However, we do not water a liter of solution this time, so we must adjust our weight accordingly. This problem can be solved by porportion.

$$\frac{500 \text{ ml}}{1000 \text{ ml}} = \frac{x \text{ gm}}{56 \text{ gm}}$$

$$x = 28 \text{ gm}$$

Example: How many grams of Ammonium Oxalate $(NH_4)_2\ C_2O_4$ will be required to make 720 ml of 1 N solution?

As before, we determine the equivalent weight of the substance

N	=	14 x 2	= 28
H	=	1 x 8	= 8
C	=	12 x 2	= 24
O	=	16 x 4	= 64
$(NH_4)_2\ C_2O_4$	=		124

The valence of C_2O_4 is $^{-}2$, making the equivalent weight

$$\frac{124}{2} = 62 \text{ grams per liter (eq. wt.)}$$

Finally, adjusting for the desired volume we get

$$\frac{720 \text{ ml}}{1000 \text{ ml}} = \frac{x \text{ gm}}{62 \text{ gm}}$$

$$x = 44.64 \text{ gm required}$$

The last type of problem we will consider is the combination of a fractional normality and a particular volume of solution.

How many grams of Manganous Sulfate $MnSO_4$ will be required to make 1250 ml of .25N solution?

Mn	= 55
SO_4	= 96
	151

Mn^{++} Valence is 2

Equivalent wt. = $\frac{151}{2}$ = 75.5 gm/liter.

We wish to make a .25N solution and N = 75.5

.25 (75.5) = 18.875 gm/liter

The above figure is the grams per liter required to make one liter of a .25N solution.

Finally, we adjust for the volume we wish to make:

$$\frac{1000 \text{ ml}}{1250 \text{ ml}} = \frac{18.875 \text{ gm}}{x \text{ gm}}$$

$$x = 23.594 \text{ gm}$$

Some books and manuals express normality of solutions in a different manner. For instance you may see "Titrate with N sulfuric acid."

It is easy to convert this to a decimal if you desire. Simply substitute 1 for N and divide the fraction.

$$\frac{N}{50} = \frac{1}{50} = .02N$$

BASIC CHEMISTRY II - PROBLEMS

1. Explain the weight-volume relationship in the normal system of solutions.
2. How many grams of HCl are required for one liter of 1N solution?
3. How many grams of potassium iodide (KI) are required for one liter of 1N solution?
4. How many grams of Ammonium Chloride (NH_4Cl) are required for one liter of 1N solution?
5. How many grams of potassium cabonate (K_2CO_3) are required to make one liter of 1N solution?
6. How many grams of Sodium Thiosulfate (Na_2 (S_2O_3)) are required to make one liter of 1N solution?
7. How many grams of Nitric Acid (HNO_3) are required to make one liter of .3N solution?
8. How many grams of Sodium Hydroxide (NaOH) are required to make one liter of .01N solution?
9. How many grams of Sodium Hydroxide (NaOH) are required to make one liter of .02N solution?

10. How many grams of potassium permanganate K (MnO_4) will be required to make one liter of $\frac{N}{80}$ solution?

11. How many grams of sulfuric acid H_2SO_4 are required to make one liter of .02N solution?

12. How many grams of sodium carbonate Na_2CO_3 are required to make 360 ml of 1N solution?

13. How many grams of potassium nitrate KNO_3 are required to make 500 ml of 1N solution?

14. How many grams of sodium oxalate Na_2 (C_2O_4) are requiraed to make 1450 ml of 1N solution?

15. How many grams of calcium carbonate $CaCO_3$ are required to make 200 ml of .25N solution?

16. How many grams of hydrochloric acid are required to make 1200 ml of .0125N solution?

17. How many grams of Sodium Thiosulfate Na_2 (S_2O_3) will be required to make 1675 ml of $\frac{N}{200}$ solution?

Element	Symbol	Valence	Atomic Number	Atomic Weight Approx.
Aluminum	Al	+3	13	26.97
Calcium	Ca	+2	20	40.08
Carbon	C	+4	6	12.01
Chlorine	Cl	-1	17	35.46
Copper	Cu	+1, +2	29	63.57
Fluorine	F	-1	9	19.00
Gold	Au	+1, 3	79	197.20
Hydrogen	H	+1	1	1.01
Iron	Fe	+2, 3	26	55.85
Magnesium	Mg	+2	12	24.32
Mercury	Hg	+1, +2	80	200.61
Nickel	Ni	+2, +3	28	58.69
Nitrogen	N	+3, +5	7	14.01
Oxygen	O	-2	8	16.00
Phosphorus	P	+3, +5	15	30.98
Potassium	K	+1	19	39.10
Silicon	Si	+4	14	28.06
Silver	Ag	+1	47	107.88
Sodium	Na	+1	11	23.00
Sulfur	S	+2, 4, 6	16	32.06
Zinc	Zn	+2	30	65.38

Partial list of elements and their comparison.

ANSWER SHEET

INTRODUCTION TO CHEMISTRY

BASIC CHEMISTRY I - pg. 8-9

1. K = Potassium.

2. Atomic Weight = The weight of an atom of the element compared with the weight of an atom of oxygen, having an atomic weight of 16.

3. There are no units for atomic weights because you can apply your own unit to the system you are working in. 16 pounds oxygen will have the same number of atoms as 55.84 pounds of iron. You also can use grams and tons.

4. There are the same number of atoms in one gram atomic weight of each element. Avogardo's number 6.02 x 10^{23}

Find molecular weights:

5. HNO_3 (nitric acid) H=1, N=14, O=16(3), 1 + 14 + 48 = 63

6. NaN_3 (sodium azide) Na=23, N=14(3), 23 + 42 = 65

7. $NaHCO_3$ (sodium bicarb.) Na=23, H=1, C=12, O=16(3), 23 + 1 + 12 + 48 = 84

8. $KMnO_4$ (potassium Perm.) K=39.1, Mn=54.9, O=16(4), 39.1 + 1 + 54.9 + 64 = 158

9. CaO (lime) Ca=40, O=16, 40 + 16 = 56

10. $MnSO_4$ (manganous sulfate) Mn=54.9, S=32, O=16(4), 54.9 + 32 + 64 = 150.9

11. $Na_2S_2O_3$ (sodium thiosulfate) Na=23(2), S=32(2), O=16(2), 46 + 64 + 48 = 158

12. KI (potassium iodide) K=39.1, I=126.9, 39.1 + 126.9 = 166

13. $MnO(OH)_2$ (basic manganic oxide) Mn=54.9, O=16(3), H=1(2), 54.9 + 48 + 2 = 104.9

14. NH_4Cl (ammonia chloride) N=14, H=1(4), Cl=35.5, 14 + 4 + 35.5 = 53.5

15. Valence = The combining capacity of an element to form compounds. Valence is also the displacing power of an atom of hydrogen compared with one atom of the element.

16. $K_2(SO_4)$ (39 x 2) + 32 + (16 x 4) = 174, 174 ÷ 2 = 87

17. NaOH 23 + 16 + 1 = 40

18. $Ca(OH)_2$ 40 + (16 x 2) + (1 x 2) = 74, 74 ÷ 2 = 37

19. Mn (SO_4) 55 + 32 + (16 x 4) = 151, 151 ÷ 2 = 75.5

20. $NaNO_3$ 23 + 14 + (16 x 3) = 85

21. CaO $40 + 16 = 56$, $56 \div 2 = 28$

22. $BaSO_4$ $137 + 32 + (16 \times 4) = 233$, $233 \div 2 = 116.5$

23. $Na_2(S_2O_3)$ $(23 \times 2) + (32 \times 2) + (16 \times 3) = 158$, $158 \div 2 = 79$

24. $K_2(CO_3)$ $(39 \times 2) + 12 + (16 \times 3) = 138$, $138 \div 2 = 69$

25. H_2SO_4 $(1 \times 2) + 32 + (16 \times 4) = 98$, $98 \div 2 = 49$

26. H_2CO_3 $(1 \times 2) + 12 + (16 \times 3) = 62$, $62 \div 2 = 31$

27. H_2S $(1 \times 2) + 32 = 34$, $34 \div 2 = 17$

ANSWER SHEET

INTRODUCTION TO CHEMISTRY

BASIC CHEMISTRY II - pg. 16-17

1. Weight - Volume relationship - One gram equivalent weight of solute per liter of solution equals a one normal solution (1N).

   Example: 10 lbs. salt in 20 gallons of water would be equal in strength to 5 lbs salt in 10 gallons of water.

2. HCl - 1 liter of 1 N solution = H=1, Cl = 35.5, 1 + 35.5 = 36.5
   36.5 grams/liter = 1 N HCl.

3. KI - 1 liter of 1 N solution: K=39.1, I=126.9, 39.1 + 126.9 = 166
   166 g/L = 1 N KI.

4. NH_4Cl - 1 liter of 1N solution: N=14, H=1 x 4, Cl=35.5, 14 + 4 + 35.5 = 53.5
   53.5 g/L = 1 N NH_4Cl.

5. K_2CO_3 - 1 liter of 1 N solution: K=39 x 2, C=12, O=16 x 3, 78 + 12 + 48 = 138
   138 ÷ 2 = 69 g/L = 1 N K_2CO_3.

6. $Na_2 (S_2O_3)$ - 1 liter of 1 N solution: Na=23 x 2, S = 32 x 2, O = 16 x 3,
   46 + 64 + 48 = 158 158 ÷ 2 = 79 79 g/L = 1 N $Na_2 (S_2O_3)$.

7. HNO_3 - 1 liter of .3N solution: H=1, N=14, O=16 x 3, 1 + 14 + 48 = 68
   63 g/L = 1 N solution. We want 0.3 N: $\frac{63\ g/L}{1\ N} : \frac{x\ g/L}{0.3\ N}$, 18.9 g/L = 0.3 N HNO_3

8. NaOH - 1 liter of .01N solution: Na=23, O=16, H=1, 23 + 16 + 1 = 40
   40 g/L = 1 N solution. We want .01N: $\frac{40\ g/L}{1N} : \frac{x\ g/L}{.01N}$ x = .4 g/L = .01N NaOH

9. NaOH - 1 liter of 0.02N solution: Na=23, O=16, H=1, 23 + 16 + 1 = 40
   40 g/L = 1N. We want .02 N $\frac{40\ g/L}{1N} : \frac{x\ g/L}{.02N}$ x = .8 g/L = .02N

10. $KMNO_4$ - 1 liter of $\frac{N}{80}$ solution: K=39.1, MN=54.9, O=16 x 4, 39.1 + 54.9 + 64 = 158

    158 g/L = 1N $KMNO_4$. We want $\frac{N}{80} : \frac{N}{80} = \frac{1N}{80}$ = .0125, $\frac{158\ g/L}{1N} : \frac{x\ g/L}{.0125N.}$

11. H_2SO_4 - 1 liter of .02N solution: H=1 x 2, S=32, O=16 x 4, 2 + 32 + 64 = 98
    98 ÷ 2 = 49 g/L = 1N, $\frac{49\ g/L}{1N} : \frac{x\ g/L}{.02N}$ x = .98 g/L = .02N H_2SO_4

12. Na_2CO_3 - 360 mL. of 1 N solution: Na=23 x 2, C=12, O=16 x 3, 46 + 12 + 48 = 106
$Na_2^{+2}CO_3^{-2}$, 106 ÷ 2 = 53, $\frac{53 \text{ grams}}{1000 \text{ mL}} : \frac{x \text{ grams}}{360 \text{ mL}}$ $\frac{1000X}{1000} = \frac{19080}{1000}$ x = 19.08 $\frac{\text{Grams}}{360 \text{ mL}}$

13. KNO_3 - 500 mL of 1 N solution: K=39, N=14, O=16 x 3, 39 + 14 + 48 = 101
101 G/L = 1 N $\frac{101 \text{ grams}}{1000 \text{ mL}}$ x $\frac{x \text{ grams}}{500 \text{ mL}}$ x = 50.5 $\frac{\text{grams}}{500 \text{ mL}}$ 1N

14. $Na_2(C_2O_4)$ - 1450 mL of 1 N solution: Na=23 x 2, C=12 x 2, O=16 x 4
46 + 24 + 64 = 134 $Na_2^{+2}(C_2O_4)^{-2}$ 134 ÷ 2 = 67 g/L = 1 N
$\frac{67 \text{ grams}}{1000 \text{ mL}} : \frac{x}{1450 \text{ mL}}$ x = 97.15 $\frac{\text{grams}}{1450 \text{ mL}}$ 1 N

15. $CaCO_3$ - 200 mL of .25 N solution: Ca=40, C-12, O=16 x 3, 40 + 12 + 48 = 100
$Ca^{+2}CO_3^{-2}$, 100 ÷ 2 = 50, 50 g/L = 1N $CaCO_3$, $\frac{50 \text{ g}}{1000 \text{ mL}} : \frac{x \text{ g}}{200 \text{ mL}}$, x = 10 g/200 mL = 1N
$\frac{10 \text{ g}/200 \text{ mL}}{1N} : \frac{y}{.25 \text{ N}}$, y = 2.5 $\frac{\text{grams}}{200 \text{ ml}}$ = .25 N $CaCO_3$

16. HCl - 1200 mL of .0125 N solution: H=1, Cl=35.5, 1 + 35.5 = 36.5
36.5 g/L = 1 N HCl $\frac{36.5 \text{ g/L}}{1 \text{ N}} : \frac{x \text{ g/L}}{.0125 \text{ N}}$ x = .456 g/L = .0125 N
$\frac{.456 \text{ grams}}{1000 \text{ mL}} : \frac{y \text{ grams}}{1200 \text{ mL}}$ y = .5472 $\frac{\text{grams}}{1200 \text{ mL}}$ .0125 N

17. $Na_2(S_2O_3)$ for 1675 mL of $\frac{N}{200}$ solution: $\frac{N}{200}$ = .005 N
Na=23 x 2, S=32.2, O=16x3, 46 + 64 + 48 = 158 $Na_2^{+2}(S_2O_3)^{-2}$,
158 ÷ 2 = 79 g/L = 1N, $\frac{79 \text{ grams}}{1000 \text{ mL}} : \frac{x \text{ grams}}{1675 \text{ mL}}$ x = 132.325 $\frac{\text{Grams}}{1675 \text{ mL}}$ 1N
$\frac{132.325 \text{ grams}/1675 \text{ ml}}{1 \text{ N}} : \frac{y \text{ grams}}{.005}$, y = .6616, .6616 $\frac{\text{Grams}}{1675 \text{ mL}}$ for $\frac{N}{200}$ solution.

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